CONSTRUCTION QUALITY ASSURANCE REPORT FOR CELL E-6 (Partial) WAIMANALO GULCH SANITARY LANDFILL KAPOLEI, OʻAHU, HAWAIʻI

Prepared for:

Waste Management of Hawaii
92-460 Farrington Highway
Kapolei, Hawaiʻi 96707

Prepared by:

AECOM Technical Services, Inc.
1001 Bishop St., Suite 1600
Honolulu, Hawaiʻi 96813-3698

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ACRONYMS AND ABBREVIATIONS

%	percent
AECOM	AECOM Technical Services, Inc.
AEG	American Environmental Group, Ltd.
ASTM	American Society for Testing and Materials
cm/sec	centimeters per second
CQA	Construction Quality Assurance
ft	feet
ft^2	square feet
g/cm^3	grams per cubic meter
GCL	geosynthetic clay liner
GSE	GSE Lining Technology, Inc.
HDPE	high density polyethylene
ID	identification
lb/ft^2	pounds per square foot
lb/in	pounds per inch
LCRS	leachate collection and removal system
Lf	lineal feet
MD	machine direction
MSW	municipal solid waste
NWL	Non-woven Thermal Lock
oz/yd^2	ounce per square yard
P.E.	Professional Engineer
pcf	pounds per cubic foot
ppi	pounds per inch
psf	pounds per square foot
psi	pounds per square inch
QC	quality control
RFI	Request for Information
SDR	standard dimension ratio
TD	transverse direction
WGSL	Waimanalo Gulch Sanitary Landfill
yd^3	cubic yard

WMH000986

1.0 INTRODUCTION

Waimanalo Gulch Sanitary Landfill (WGSL) is an active municipal solid waste (MSW) disposal facility located at 92-460 Farrington Highway in Kapolei, Hawai'i. This report presents documentation and certification of the recently constructed MSW Cell E-6 (Partial), including the E-6 sump.

Cell E-6 consists of approximately 7 acres. The recently constructed portion of the cell (E-6 Partial) includes a western sideslope area with a 1.5 horizontal to 1 vertical (1.5H:1V) or flatter gradient and a sump and floor area. Cell E-6 (Partial) is located to the west of existing municipal solid waste (MSW) Cells 11 and E-4. The partial liner area consists of approximately 3.5 acres (152,549 square feet [ft^2]) and is shown on Drawing 1 in Appendix I. The single composite lining system for Cell E-6 consists of the following components, from top to bottom:

- 24- and 36-inch-thick operations layer (24 inches on sideslope/floor and 36 inches on termination bench)
- 10 ounces per square yard (oz/yd^2) geotextile
- Leachate collection and removal system (LCRS) consisting of perforated 6-inch high density polyethylene (HDPE) pipe surrounded by drainage gravel layer
- 16 oz/yd^2 geotextile
- 60-mil HDPE double-sided textured geomembrane liner
- Geosynthetic clay liner (GCL)
- 40-mil HDPE double-sided textured geomembrane liner
- 12-inch-thick soil cushion layer

In addition to the components listed above, in the E-6 sump area, an additional composite liner system consisting of the following components (from top to bottom), is located above the 12-inch-thick soil cushion layer and below the single composite liner system listed above:

- 60-mil HDPE double-sided textured geomembrane liner
- GCL
- 40-mil HDPE double-sided textured geomembrane liner

General - may also want to describe the riser pipes and the geomembrane rubsheet below the riser pipes since they were HDOH requests. Also, may want to include the pump information.

WGSL's current permit requires certification by a Registered Professional Engineer (P.E.) that the lining system and leachate management system components were constructed in compliance with the permit requirements, the approved Construction Quality Assurance (CQA) Plan, and the approved design drawings. This report documents the CQA tasks performed by AECOM Technical Services, Inc. (AECOM) during construction of the geosynthetic liner system components, and the leachate management system components in Cell E-6 (Partial). Major development activities associated with Cell E-6 (Partial) construction documented in this report include:

- Subgrade preparation
- Installation of the geomembrane liner
- Installation of the GCL
- Installation of geotextile cushion and filter materials
- Installation of LCRS and gas extraction riser pipes
- Installation of leachate collection pipe

- Placement of the leachate drainage layer material
- Placement of operations layer material

AECOM provided full-time CQA monitoring and testing services to verify that the components of the landfill were constructed in compliance with permit requirements. The documentation also includes survey work by Park Engineering (State of Hawaii licensed surveyor) throughout the project. The survey information was used to provide as-built conditions of the work.

1.1 PROJECT DESCRIPTION

WGSL is divided into multiple cells. During cell construction, a new liner and LCRS is installed and connected to the existing landfill cells. Subsequently, municipal solid waste is placed in each cell. On June 4, 2010, the State of Hawaii Department of Health renewed the operating permit (No. LF-0182-09) to include a lateral expansion, which includes the construction of Cells E-5 through E-9.

Cell E-6 (Partial) is located west of the northern portions of existing MSW Cell 11 and Cell E-4. This CQA report documents construction activities for Cell E-6 (Partial).

Project Participants. The principal participants in the Cell E-6 (Partial) construction project at WGSL and their respective roles are noted below:

1.1.1 Construction Activities and Participants:

- Landfill Design – Geosyntec Consultants, Inc., Oakland Creek, California
- Drainage Design – GEI Consultants, Oakland, California
- Earthwork – Goodfellow Bros., Inc., Waipahu, Hawai'i
- Surveyor – Park Engineering, Honolulu, Hawai'i
- Soil Testing Laboratory – Masa Fujioka and Associates, Aiea, Hawai'i
- Geomembrane and Geotextile Manufacturer – GSE Lining Technology, Inc. (GSE), Houston, Texas
- Geosynthetic Materials Installation Contractor – American Environmental Group, Ltd. (AEG) Richfield, Ohio – are they independent from GSE or are they a subsidiary?
- Geosynthetic Clay Liner Manufacturer – GSE BentoLiner, Inc., Spearfish, South Dakota – is it described as Bentofix NWL-60?

1.1.2 Construction Quality Assurance Activities and Participants:

- Construction Quality Assurance Consultant – AECOM, Honolulu, Hawai'i
- Construction Quality Assurance Geotechnical Laboratory – Masa Fujioka and Associates, Aiea, Hawai'i
- Construction Quality Assurance Concrete Laboratory – Construction Engineering Laboratories, Pearl City, Hawai'i
- Construction Quality Assurance Geosynthetic Laboratory (interface friction and conformance testing) – TRI / Environmental, Inc. Austin, Texas
- Construction Quality Assurance Geosynthetic Laboratory (Destructive seam testing) – Precision Geosynthetic Laboratories, Anaheim, California

1.2 REFERENCE DOCUMENTS

The following documents were used for reference and guidance during the course of this project.

- Geosyntec Consultants, Inc. 2010. (Geosyntec, 2010). *Technical Specifications and Construction Drawings, Cells E-6 through E-8, Waimanalo Gulch Landfill, Ewa Beach, O'ahu, Hawai'i, Dated January 2010. with revisions dated 11 February, 11 March, and 16 March 2010.*
- Geosyntec Consultants, Inc. and GEI Consultants, Inc. 2010. (Geosyntec and GEI, 2010). *Construction Quality Assurance (CQA) Plan, Waimanalo Gulch Landfill, Ewa Beach, O'ahu, Hawai'i, Dated January 2010.*
- Current operating *Permit LF-0182-09* dated June 4, 2010.

1.3 SUMMARY OF CQA PLAN AND ACTIVITIES

The CQA Plan establishes criteria for the following:

- CQA personnel qualifications
- Observation activities
- Sampling
- Testing methods and frequencies
- Construction documentation

AECOM verified the construction by observing, testing, and documenting the construction in compliance with the CQA Plan. CQA activities to document the work performed consisted of the following:

- Observing and recording all construction activities for compliance with the project documents.
- Obtaining samples of construction materials during placement activities.
- Performing field testing of constructed items.
- Preparing this CQA Report certifying that construction was in accordance with the project requirements.

A more detailed description of the CQA activities is included in Section 3.0.

1.4 REPORT ORGANIZATION

Section 1.0 provides an introduction to the report.

Section 2.0 summarizes Cell E-6 (Partial) construction activities.

Section 3.0 summarizes CQA activities for Cell E-6 (Partial).

Section 4.0 summarizes the conclusions of this report.

2.0 SUMMARY OF CELL E-6 (PARTIAL) CONSTRUCTION ACTIVITIES

This section of the report summarizes the construction methods and activities employed to construct Cell E-6 (Partial) according to project Technical Specifications (Geosyntec 2010).

2.1 CONSTRUCTION SUMMARY AND SCHEDULE

The Cell E-6 (Partial) area is 152,549 ft^2 based on the as-built survey for the project (see Drawing 1, Appendix I). The cell's construction began with the preparation of the subgrade for the cell floor, tie-in to Cell 11, tie-in to Cell E-4, and the 1.5H:1V gradient western sideslope.

The following schedule in Table 2-1 lists the start dates and completion dates of the prominent phases during construction of Cell E-6 (Partial).

Table 2-1: Construction Completion Schedule

Task	Start Date	Completion Date
Subgrade Preparation	7/29/10	9/17/10
Geosynthetics Installation	8/6/10	9/18/10
LCRS	9/23/10	10/6/10
Operations Layer	9/30/10	10/6/10

2.2 SURVEY CONTROL

Survey control was provided by Park Engineering and was supplemented by global positioning system survey control by the earthwork contractor, Goodfellow Bros., Inc. The main function of the survey work performed during cell construction was to define the tie-in to the existing cells, establish design grades, determine as-built grades, and document the limits of construction.

2.3 CELL E-6 (PARTIAL) CONSTRUCTION

2.3.1 Subgrade and Soil Cushion Layer Preparation

In general, the subgrade for the Cell E-6 (Partial) liner consisted of competent basalt/bedrock excavated and graded to establish proper grades on the cell floor and 1.5H:1V sideslope.

As part of the Western Surface Water Drainage Project, 18-inch and 36-inch diameter HDPE drainage pipes were installed in a north-south direction within the Cell E-6 (Partial) subgrade, below final liner grades. The 36-inch diameter HDPE pipe were placed within trenches excavated into competent basalt/bedrock and backfilled with controlled low strength material (CLSM) up to 6 inches over the crown of the pipe. A 3-inch minus trench backfill was placed above the 36-inch diameter HDPE/CLSM to fill in the excavated trench to reach design subgrade elevations prior to placement of soil cushion. The trench dimension was approximately 2-feet (ft)-deep by 4-ft-wide, but was deeper in the area of the 450-ft subgrade contour (up to 10 ft deep) due to surrounding existing grades. The 3-inch minus material was placed in maximum loose lifts of 8 inches, and compacted to meet project specifications.

The bedrock/trench backfill/CLSM was overlain by a 12-inch thick soil cushion layer produced from onsite crushing and screening operations. The material was placed on the floor and sideslope with a D6 Caterpillar dozer at a maximum compacted thickness of 6 inches (maximum loose lift thickness of 8 inches).

After placement of the soil cushion layer, the surface was compacted by track-walking with a D6 Caterpillar dozer, by rolling with a drum roller attached to an excavator on the sideslope and a Dynapac vibratory roller CA362D operated at 1,800 rpm on the cell floor. Water was applied with a water truck as necessary to achieve moisture contents necessary for compaction. In addition, water was mixed with the soil cushion material using an excavator prior to placement on the sideslope.

Prior to deployment of the geomembrane, the finished surface of the soil cushion layer was observed by AECOM and AEG for the presence of unsuitable conditions such as stones, wet spots, ruts, and soft areas. All areas observed with unsuitable conditions were corrected prior to acceptance of the surface. The acceptance procedure for the soil cushion surface is described in Section 3.2.4.

2.3.2 Geomembrane Installation

2.3.2.1 Geomembrane Material

The geomembrane used in the project included both 40-mil and 60-mil double-sided black textured HDPE manufactured by GSE. During the project, approximately 189,420 ft^2 of 40-mil textured HDPE geomembrane and 190,707 ft^2 of 60-mil textured HDPE geomembrane were deployed.

2.3.2.2 Geomembrane Deployment

A total of 122 individual panels were installed from the 60-mil geomembrane rolls and 123 individual panels were installed from the 40-mil geomembrane rolls.

The geomembrane panel deployment began with the 40-mil material in the E-6 sump as part of the double composite liner system. The geomembrane was transported to the placement area using a forklift equipped with a spreader bar to hold the geomembrane rolls. When the forklift was positioned where a roll was to be deployed, the material was pulled by hand into place.

Following placement of the 40-mil geomembrane, GCL was deployed, as described in Section 2.3.3, followed by the 60-mil geomembrane. An encapsulating weld was placed along all perimeter edges of the Cell E-6 panels to encapsulate the GCL within the 40-mil and 60-mil geomembrane materials, as shown on the project Construction Drawings (Geosyntec 2010).

Following placement of the 40-mil geomembrane, GCL and 60-mil geomembrane layers in the E-6 sump, deployment continued in a similar manner with an additional 40-mil geomembrane, GCL and 60-mil geomembrane layer with encapsulating weld to complete the double composite liner system in the sump area. Once deployment of the double composite liner system in the E-6 sump was completed, deployment of the single composite liner system (40-mil geomembrane, GCL and 60-mil geomembrane) continued north of the sump in the remainder of E-6 (Partial).

Question – are the limits of the double-liner shown anywhere?

For installation of geosynthetics from the western slope runout bench, the installer was allowed to drive the forklift over the previously installed geosynthetic layers to install the overlying layers. Per RFI No. 044 and 049, protective measures using plywood pieces covered in geotextile were approved to prevent damage to the 40-mil geomembrane and GCL. The RFI Nos. 044 and 049 are summarized in Section 3.9 and are presented in Appendix J.

During panel deployment, the panel identification number and roll number were recorded on each panel and logged on panel placement forms. Panel installation information is summarized in more detail in Section 3.3.3 of this report. The layouts of the 40-mil and 60-mil geomembrane panels are shown in Appendix I on Drawings 2 through 7 respectively. In general, the geomembrane was installed in a loose, relaxed condition. As the panels were placed, they were aligned down the slopes and adjusted for a nominal 6-inch overlap. Free edges of the geomembrane were temporarily weighted with sandbags during deployment to prevent uplift and displacement due to wind.

2.3.2.3 Geomembrane Welding

During geomembrane installation, welding was performed using either the fusion or extrusion method, with fusion seaming being the primary method. Upon completion of welding, each seam was tested for integrity and continuity using non-destructive and destructive test methods described in Sections 3.3.6 and 3.3.7, respectively.

The extrusion welding procedure was used primarily for the encapsulating weld along the Cell 11 and Cell E-4 tie-in, and the encapsulating weld anchor trench. Also, extrusion seams were made at repair locations and other locations where fusion welding could not be performed. A more detailed description of each of the welding methods is presented in the following paragraphs.

Fusion Welding. To produce a fusion-welded seam, an AEG technician first prepares the surfaces to be welded by wiping the geomembrane panel edges clean and trimming excess overlap. The edges of the two panels are then placed into the welding machine. Two "hot-wedges" heat the geomembrane surfaces of both panels to molten material. The melted surfaces of the top and bottom layers of the overlap are then compressed by the drive rollers of the welding machine. In this way the welding machine produces two parallel fusion welds, or "tracks," with a small air channel between them. The air channel is used for non-destructive continuity testing of the fusion weld, as discussed in Section 3.3.6.

AEG seaming technicians continually monitored the seaming operations and adjusted settings on the welding machine as necessary.

Extrusion Welding. To produce an extrusion weld, two pieces of geomembrane are temporarily tack welded together with a heat gun. Once tacked together, the edges of the two-geomembrane surfaces are then ground to provide a clean rough surface on which to place the extrusion weld. A technician then uses a semi-automatic hand-held extrusion welding machine to produce the extrusion seam.

AEG seaming technicians continually monitored the seaming operations and adjusted settings on the extrusion welder as necessary.

2.3.2.4 Geomembrane Repairs

Repairs to the geomembrane were required for several reasons that include cross seams, geomembrane damage, and repair of seam samples removed for destructive testing.

Also, during the course of the observation and testing procedures, each geomembrane panel and seam was visually observed and monitored for defects and damage. These observations were made on an on-going basis throughout the installation. Observed defects were noted, logged, and marked for repair by AECOM and repaired by AEG.

Repairs to the geomembrane were made using the procedures described in this section and were non-destructively tested.

The repairs and defects requiring patches were documented by recording the date repaired, location, description of damage, size and type of repair, crew that made the repair, date and technician that conducted the non-destructive test on the repair. Repairs were subject to the same quality assurance procedures as the field seams including pre-production testing and vacuum box testing.

Dates and locations of repairs to the geomembrane are discussed in Section 3.3.8.

The geomembrane layer was considered finished and approved when all testing was completed and all test information on the geomembrane surface was documented and all repair work was completed, retested, and passed. A final walkover of the completed geomembrane was performed by AECOM and AEG to ensure that all required work had been completed and documented.

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2.3.3 GCL Installation

The GCL used in this project was BentoLiner Non-woven Thermal Lock (NWL)-60 GCL and was manufactured by GSE BentoLiner, Inc. During the project, approximately 201,144 ft^2 of GCL was deployed. The area of deployed material is greater than the area of cell construction due to overlaps at seams, tie-in, and anchor trench.

The GCL was deployed with a fork-lift equipped with a carpet rod. The rolls were positioned at the top of the slope and pulled down by hand. Horizontal seams were installed as necessary per the procedures and requirements outlined in RFI No. 26, which is summarized in Section 3.9 and presented in Appendix J. All adjacent panels of GCL were overlapped a minimum of 18 inches and bentonite was applied at a rate of 1/4 pound per ft of seam. The E-6 (Partial) GCL was connected to the existing Cell E-4 and Cell 11, by overlapping a minimum of 36 inches.

2.3.4 Geotextile Installation

A 16 oz/yd^2 geotextile was installed as a base cushion over the geomembrane of Cell E-6 (Partial). During the project, approximately 166,500 ft^2 of 16 oz/yd^2 geotextile was deployed. The area of deployed material is greater than the area of cell construction due to overlaps at seams, tie-in, and anchor trench. The geotextile panels were placed by hand, overlapped a minimum of 3 inches, and sewn in place with a double-stitched "prayer" seam.

A 10 oz/yd^2 geotextile was installed as a filter layer the LCRS drainage gravel of Cell E-6 (Partial). During the project, approximately 112,500 ft^2 of 10 oz/yd^2 geotextile was deployed. Geotextile in areas that had received 3" minus backfill to achieve final grade were overlapped a minimum of 3 inches, and sewn in place with a double-stitched "prayer" seam. This area included the northern edge Cell E-6 (Partial), north of the 440-ft contour. Areas outside of the backfilled area were overlapped with a 3-ft overlap, shingled with the up-canyon layer over the down-canyon layer, as outlined in RFI No. 53 (which is summarized in Section 3.9 and presented in Appendix J).

2.3.5 New Liner Tie-in to Existing Liner

The new Cell E-6 (Partial) geosynthetic liner materials (GCL, geomembrane, and geotextile) were connected to the existing MSW Cell E-4 and Cell 11 liner components to form a continuous liner. The liners were connected per the details shown on the drawings on the project Construction Drawings (Geosyntec 2010).

2.3.6 Liner Termination Construction

The liner termination western edge of Cell E-6 (Partial) sideslope was constructed in accordance with the project Construction Drawings (Geosyntec 2010) and included a 15-ft minimum runout on the termination bench. Following geosynthetics deployment, 3 ft of operations layer was placed as shown on the project Construction Drawings (Geosyntec 2010). A 4.5-ft high stormwater diversion berm was constructed along the floor of the temporary northern liner termination in order to prevent stormwater run-on resulting in increased leachate generation.

2.3.7 LCRS Riser Pipe Installation

A 24-inch diameter, standard dimension ratio (SDR)-11, HDPE, perforated LCRS riser pipe was installed in the low elevation point of the sump area. The pipe was carefully placed over the installed sump liner material using a sling mounted on an excavator bucket. An 18-inch diameter, SDR-11, HDPE, perforated LCRS gas riser pipe was installed just to the north of the 24-inch diameter pipe using similar methods. A piece of 60-mil HDPE geomembrane rub sheet was placed underneath each of the riser pipes in the floor of the sump.

2.3.8 LCRS Collection Pipe Installation

Approximately 650 ft of 6-inch diameter, SDR-11, HDPE, perforated LCRS collection pipe was installed in a north/south direction along the floor of Cell E-6 (Partial). The pipe was welded outside of the cell and transported to the cell by Goodfellow Bros. personnel. The northern edge of the pipe was left exposed to allow for continuation of the pipe for the remainder of Cell E-6. The leachate collection pipe was perforated with 5/16-inch holes, according to project specifications. The location of the leachate collection pipe is shown in Appendix I on Drawing 1.

2.3.9 LCRS Gas Extraction Pipe Installation

Approximately 180 ft of 6-inch diameter, SDR-11, HDPE, perforated gas extraction pipe was installed in a north/south direction within the sump area, on top of the 10 oz/yd^2 geotextile filter layer and connected to the 18-inch riser pipe. The pipe was welded outside of the cell and transported to the cell by Goodfellow Bros. personnel. The pipe was perforated with 5/16-inch holes, according to project specifications. The location of the gas extraction pipe is shown in Appendix I on Drawing 8.

May need to include pipe welder certificates for GBI.

2.3.10 LCRS Drainage Gravel Installation

LCRS drainage gravel was placed on the floor and up the sideslope 10 ft, as shown on the project Construction Drawings (Geosyntec 2010). The LCRS drainage gravel was placed 3-ft-thick in the sump area and 1-ft-thick in other areas. A majority of the LCRS drainage gravel was imported from an offsite quarry operation (Halawa), with a smaller amount generated from onsite sources. In general, a front end loader was used to haul and place the stone along 3-ft-thick temporary access roads across the Cell E-6 (Partial) floor, followed by an excavator that spread the material out across the floor and up the sideslopes in a 1-ft-thick lift. The LCRS drainage gravel material met the project requirements and was placed as outlined in RFI No. 52.1 (which is summarized in Section 3.9 and presented in Appendix J). Laboratory testing was conducted on the material and is described further in Section 3.2.5.

2.3.11 Operations Layer Installation

The operations layer consisted of onsite crushed/screened stone material placed in a 2-ft-thick (minimum) layer placed on the cell floor, and extended 10 ft up the sideslope as shown on the project Construction Drawings (Geosyntec 2010). Additionally, onsite crushed/screened sand material was placed in a 3-ft-thick operations layer above the termination bench for Cell E-6 (Partial). The remainder of the operations layer will be placed by Waste Management further up the sideslope as MSW is placed in the cell.

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3.0 CONSTRUCTION QUALITY ASSURANCE ACTIVITIES, CELL E-6 (PARTIAL)

This section of the report summarizes the CQA activities and procedures employed in the construction of Cell E-6 (Partial) to ensure project requirements and specifications were met.

3.1 AECOM CQA PROJECT PERSONNEL

AECOM's project team consisted of the following members:

- Project Manager and CQA Officer: Ron Boyle, P.E.
- CQA Monitors: Dan Braatz, Dan Frerich, and Russ Kotrba

The CQA officer/project manager performed oversight for the documentation procedure including both fieldwork and report preparation. The CQA officer also prepared the documentation report and provided the engineering certification. The CQA officer's statement is included in Appendix A.

The CQA monitors were responsible for onsite observation, testing, sampling, and documentation. They were also responsible for preparing a daily field report /summary of field activities. Daily field reports are included in Appendix B of this report. Additionally, CQA monitors inventoried the rolls of GCL, geomembrane, and geotextile; inventories are provided in Appendix G.

3.2 EARTHWORK OBSERVATION

Observation of the earthwork is summarized below. Soil laboratory test results are presented in Appendix C.

3.2.1 Subgrade and Geologic Inspection

Geological conditions for potential water seepage in the excavated area of Cell E-6 (Partial) was inspected and evaluated during the excavation of Cell E-6 (Partial). Based on the visual inspections conducted for the Cell E-6 (Partial) sideslopes, no geological conditions were observed to indicate the presence of water seepage in the cell; therefore, no mitigation measures for controlling water seepage beneath the landfill liner system were required.

3.2.2 Pipe and CLSM

As part of the Western Surface Water Drainage Project, an 18-inch and 36-inch HDPE pipe were installed in portions of the Cell E-6 (Partial) subgrade. The HDPE pipes were placed within trenches excavated into competent basalt/bedrock and covered with CLSM up to 6 inches over the crown of the pipe, as shown in the project Construction Drawings (Geosyntec 2010).

Test cylinders of the CLSM were collected by Construction Engineering Labs and submitted for 7-day and 28-day compressive strength testing. A total of 3 samples (10 cylinders) were collected from the CLSM poured in Cell E-6 (Partial). All CLSM strength tests met or exceeded the minimum strength requirements of a compressive 28-day strength of 150 psi (modification to original specification is presented in Section 3.9 and included in RFI No. 50 in Appendix J). CLSM test results are summarized in Table 3-1 and presented in Appendix C. Approximately 480 lineal feet (lf) of the 18-inch and 850 lf of the 36-inch HPDE pipe (a total of 1,330 lf) were installed resulting in a testing frequency of one test per 443 lf of pipe. Therefore, the minimum sampling frequency of one test per 500 lf of pipe was met.

As-builts and additional information on the HDPE pipes and CLSM will be documented separately upon completion of the Western Surface Water Drainage Project.

Table 3-1: CLSM Testing Results

Sample Date	Sample ID	Sample Location	Test Performed	Compressive Strength (spec value = 28-day of 150 psi)	Met Project Requirement?
6/28/10	1-A	18" HDPE, western slope termination bench of Cell E-6	7-day compressive strength	190	Yes
	1-B	18" HDPE, western slope termination bench of Cell E-6	7-day compressive strength	160	Yes
	1-C	18" HDPE, western slope termination bench of Cell E-6	28-day compressive strength	220	Yes
	1-D	18" HDPE, western slope termination bench of Cell E-6	28-day compressive strength	200	Yes
7/19/10	1-A	36" HDPE, floor of Cell E-6	1-day compressive strength	110	No
	1-B	36" HDPE, floor of Cell E-6	7-day compressive strength	310	Yes
	1-C	36" HDPE, floor of Cell E-6	28-day compressive strength	460	Yes
7/29/10	1-A	36" HDPE, floor of Cell E-6	1-day compressive strength	90	No
	1-B	36" HDPE, floor of Cell E-6	7-day compressive strength	140	No
	1-C	36" HDPE, floor of Cell E-6	28-day compressive strength	150	Yes

ID identification
psi pound per square inch

3.2.3 Trench Backfill

Trench backfill (3-inch minus material) was placed above the 36-inch HDPE pipe that passes under the floor of Cell E-6 as part of the Western Surface Water Drainage Project. Trench backfill above the pipe was placed approximately 2-ft-thick by 4-ft-wide (along subgrade design contour of 450 ft, fill was up to 10 ft deep) and compacted in lifts with a maximum compacted thickness of 6 inches (maximum loose lift thickness of 8 inches).

Sand cone density (ASTM D1156) and sieve analysis (D422) testing was performed on the 3-inch engineered fill material by Masa Fujioka and Associates personnel to ensure material met the minimum dry density requirement 122 pcf, as outlined by the design engineer (Geosyntec) in the modification to the project Technical Specifications (Geosyntec 2010) Section 02249, Compacted Soil. A copy of the modification to the project technical specifications is summarized in Section 3.9 and included in Appendix J. Laboratory results and sand cone density test results are summarized in Table 3-3 and presented in Appendix C.

A total of 5 sand cone density testing (ASTM D1156) and sieve analysis (D422) were performed on the 3-inch trench backfill prior to placement of the soil cushion layer. Sample IDs included DT-50 through DT-54. Note that samples DT-1 through DT-49 were taken in embankment fill north of Cell E-6 (Partial) and will be presented in subsequent CQA reports for Cell E-6 and E-7.

All sand cone density tests met or exceeded the specified minimum dry density requirement of 122 pcf. Density test results are summarized in Table 3-32 and presented in Appendix C. The locations of the density tests are presented on Drawing 1, in Appendix I. Approximately 1,500 yd^3 of

3-inch minus material was placed as part of the subgrade for Cell E-6 (Partial) resulting in a testing frequency of one test per 300 yd^3. Therefore the minimum sampling frequency of one test per 3,000 yd^3 for sand cone and one test per 5,000 yd^3 for sieve analysis was met (testing frequency per the modification to the project technical specifications summarized in Section 3.9 and presented in Appendix J).

Table 3-2: 3-Embankment Fill and Trench Backfill Test Results

Sample ID	Sample Location	Test Performed	% Passing 3-inch Sieve (spec value = 100)	Dry Density (min. spec value = 122 pcf)	Met Project Requirement?
DT-50	3-inch minus fill over 36-inch HDPE pipe	Sieve and sand cone Density	100	136.5	Yes
DT-51	3-inch minus fill over 36-inch HDPE pipe	Sieve and sand cone Density	100	141.5	Yes
DT-52	3-inch minus fill over 36-inch HDPE pipe	Sieve and sand cone Density	100	127.4	Yes
DT-53	3-inch minus fill over 36-inch HDPE pipe	Sieve and sand cone Density	100	142.9	Yes
DT-54	3-inch minus fill over 36-inch HDPE pipe	Sieve and sand cone Density	100	131.5	Yes

ID identification
pcf pound per cubic foot

3.2.4 Soil Cushion Layer Surface Acceptance

AECOM provided periodic observation of the soil cushion layer placement/compaction and provided full time observation of the critical tie-in excavation processes. Goodfellow Bros. maintained responsibility for the grade and preparation of the subgrade. AECOM verified through visual observations that the soil cushion layer was a minimum 12 inches thick.

The CQA monitor observed the finish grading and compaction of the completed subgrade with a D6 Caterpillar Dozer, and by rolling with a drummed roller attached to an excavator on the side slopes, and a Dynapac Vibratory Roller on the floor. Onsite crushed/screened sand material was used to construct the soil cushion layer. Bulk samples of the soil cushion material were collected and submitted to Masa Fujioka and Associates for sieve analysis (samples SC-03 through SC-15). Laboratory results are summarized in Table 3-3 and presented in Appendix C.1. Approximately 5,600 yd^3 of cushion layer material was placed for the soil cushion layer, resulting in a testing frequency of one test per 942 yd^3. Therefore, the minimum sampling frequency of one test per 1,500 yd^3 was met.

Table 3-3: Soil Cushion Testing Results

Sample ID	Sample Location	Test Performed	% Passing 3/8-inch Sieve (spec value = 100)	Met Project Requirements?
SC-03	Material Stockpile	Sieve and Moisture-Density Relations Curve	99.5	Yes [a]
SC-10	Soil cushion material	Sieve	97.9	Yes [a]
SC-11	Soil cushion material	Sieve	99.7	Yes [a]
SC-12	Soil cushion material	Sieve	99.2	Yes [a]
SC-13	Soil cushion material	Sieve	98.2	Yes [a]
SC-14	Soil cushion material	Sieve	95.4	Yes [a]
SC-15	Soil cushion material	Sieve	99.9	Yes [a]

ID identification
[a] see discussion in Section 3.2.4

Per RFI No. 027, the maximum particle size of the soil cushion material was increased from the 1/4-inch identified in the project Technical Specifications to 3/8-inch, with the requirement that the material be rounded to sub-rounded. The RFI is summarized in Section 3.9 and presented in Appendix J.

The material used for the cushion layer generally met project requirements for grain size distribution, which require a maximum particle size of 3/8 inch. Due to irregularities in the contractor's screens used to process the onsite rock and soil, a few particles (less than 5 percent by weight) were slightly larger than 3/8 inch. After verbal discussions with the design engineer (Geosyntec), the primary concern was that no protrusions greater than 3/8 inch existed on the rolled subgrade prior to deployment of the 40-mil HDPE geomembrane; additional requirements in Section 2225 (Subgrade Preparation) of the specifications were also followed. AECOM observed that no protrusion greater than 3/8 inch existed on the prepared subgrade; any oversized material that was observed was removed prior to deployment. In addition, AECOM verified the material was rounded to sub-rounded, using visual classification as described in ASTM D2488.

In situ nuclear gauge density testing (ASTM D2922, D3017) was performed on the soil cushion layer material by Masa Fujioka and Associates personnel to ensure material met compaction requirements of a minimum of 90 percent maximum dry density per ASTM D1557, as outlined in the Project Technical Specifications. A bulk sample of the soil cushion material (SC-03) was collected and submitted to Masa Fujioka and Associates for moisture-density relations curve testing prior to in situ nuclear gauge density testing. Laboratory results and density tests are summarized in Table 3-4 and presented in Appendix C.

Table 3-4: Soil Cushion Density Testing Results

Sample ID	Sample Location	Test Performed	Nuclear Dry Density (pcf)	Percent Compaction [a] (spec value = 90% min)	Met Project Requirements?
DT-01	Soil cushion layer under geomembrane	Nuclear Density/Moisture	105	97	Yes
DT-02	Soil cushion layer under geomembrane	Nuclear Density/Moisture	107	99	Yes
DT-03	Soil cushion layer under geomembrane	Nuclear Density/Moisture	106	98	Yes
DT-04	Soil cushion layer under geomembrane	Nuclear Density/Moisture	107	99	Yes
DT-05	Soil cushion layer under geomembrane	Nuclear Density/Moisture	108	100	Yes
DT-06	Soil cushion layer under geomembrane	Nuclear Density/Moisture	113	100+	Yes
DT-07	Soil cushion layer under geomembrane	Nuclear Density/Moisture	112	100+	Yes
DT-08	Soil cushion layer under geomembrane	Nuclear Density/Moisture	114	100+	Yes
DT-09	Soil cushion layer under geomembrane	Nuclear Density/Moisture	108	100	Yes
DT-10	Soil cushion layer under geomembrane	Nuclear Density/Moisture	106	98	Yes
DT-11	Soil cushion layer under geomembrane	Nuclear Density/Moisture	123	100+	Yes
DT-12	Soil cushion layer under geomembrane	Nuclear Density/Moisture	124	100+	Yes
DT-13	Soil cushion layer under geomembrane	Nuclear Density/Moisture	106	98	Yes

Sample ID	Sample Location	Test Performed	Nuclear Dry Density (pcf)	Percent Compaction [a] (spec value = 90% min)	Met Project Requirements?
DT-14	Soil cushion layer under geomembrane	Nuclear Density/Moisture	107	99	Yes
DT-15	Soil cushion layer under geomembrane	Nuclear Density/Moisture	112	100+	Yes
DT-16	Soil cushion layer under geomembrane	Nuclear Density/Moisture	109	100+	Yes
DT-17	Soil cushion layer under geomembrane	Nuclear Density/Moisture	101	93	Yes
DT-18	Soil cushion layer under geomembrane	Nuclear Density/Moisture	101	93	Yes
DT-19	Soil cushion layer under geomembrane	Nuclear Density/Moisture	110	100+	Yes
DT-20	Soil cushion layer under geomembrane	Nuclear Density/Moisture	109	100+	Yes
DT-21	Soil cushion layer under geomembrane	Nuclear Density/Moisture	110	100+	Yes
DT-22	Soil cushion layer under geomembrane	Nuclear Density/Moisture	110	100+	Yes
DT-23	Soil cushion layer under geomembrane	Nuclear Density/Moisture	110	100+	Yes
DT-24	Soil cushion layer under geomembrane	Nuclear Density/Moisture	108	100	Yes
DT-25	Soil cushion layer under geomembrane	Nuclear Density/Moisture	108	100	Yes
DT-26	Soil cushion layer under geomembrane	Nuclear Density/Moisture	106	98	Yes

ID identification
pcf pound per cubic foot
[a] maximum dry density = 108.0 pcf per ASTM D1557 from sample SC-03

A total of 26 in situ nuclear density tests (ASTM D2922, D3017) were performed on the soil cushion material prior to geomembrane deployment (sample IDs: DT-01 through DT-26). All density tests met or exceeded the minimum compaction requirements of 90 percent of the maximum density. The locations of the density tests are presented on Drawing 1, in Appendix I. Approximately 5,600 yd^3 of soil cushion layer material were placed for the subgrade, resulting in a testing frequency of one test per 215 yd^3 (no minimum testing frequency is specified in the project Technical Specifications or CQA Plan).

Prior to deployment of the 40-mil geomembrane, AECOM and AEG inspected the finished surface for unsuitable conditions such as stones, sharp objects, wet spots, ruts, and soft areas. If any such conditions were found, they were removed and/or repaired. When the surface was considered acceptable, both the AEG site superintendent and AECOM representative signed a form entitled "Certificate of Acceptance of Soil Subgrade Surface." This form states that the surface of the subgrade is suitable for the installation of the geosynthetics. Copies of this form are included in Appendix E.1.

3.2.5 LCRS Drainage Gravel

A 3-ft-thick layer of LCRS drainage gravel was placed in the E-6 (Partial) sump floor, and a 1-ft-thick layer was placed on the floor outside of the sump area. The material was placed 10 ft up the sideslopes as required by the project Construction Drawings. RFI 52.1 required that any material in direct contact with the liner system should have gradations similar to LCRS-14 and LCRS-15. For the upper 2 ft of the 3-ft thick LCRS drainage gravel layer required in the sump area, the material should meet the original project specifications, and RFI No. 41 that required an increased frequency of sieve analysis testing at 1 sample per 750 yd^3 to confirm that the fines content (percent passing the #200 sieve) remained below 6%. Requirements of the RFIs are summarized in Section 3.9 and presented in Appendix J.

As required by RFI No. 52.1, AECOM observed that a 1-foot thick (minimum) layer of crushed drainage gravel was placed in contact with the liner system through the entire E-6 liner floor area. The material was primarily imported from an offsite quarry (Halawa). The upper 2 ft of the 3-ft-thick LCRS gravel layer in the sump area was constructed with a 1.5-inch minus material produced on site that met the original project specifications.

Bulk samples (LCRS-13 through 19) were collected from the material to be used in Cell E-6 (Partial) LCRS construction and the material was submitted to Masa Fujioka and Associates for sieve analysis (ASTM D422) and hydraulic conductivity (ASTM D2434) testing. Approximately 4,830 yd^3 of material was placed, resulting in a testing frequency of one test per 690 yd^3 for sieve analysis, and one test per 1,208 yd^3 for hydraulic conductivity. Therefore the testing frequency requirement of one test per 750 yd^3 for sieve analysis (ASTM D422) and one test per 5,000 yd^3 for hydraulic conductivity (ASTM D2434) was achieved. The sample gradation and hydraulic conductivity results are summarized in Table 3-5 and presented in Appendix C.2.

The test results indicated that the material achieved the drainage gravel specification of a minimum hydraulic conductivity of 1.0 centimeter per second (cm/sec). The sieve analysis testing results for LCRS-13, 18, and 19 indicate that the materials for the 1.5-inch minus material met the requirements established in RFI No. 41. Samples LCRS-16 and -17 have gradations similar to samples LCRS-14 and -15 that were approved in RFI No. 52.1 and are therefore considered to meet the project requirements.

Table 3-5: LCRS Drainage Gravel Laboratory Testing Results

Sample ID	Test Requested	Source and Material Type	Location Used	Hydraulic Cond. (cm/sec) (spec value >/= 1.0)	% Passing 1.5-inch Sieve (spec value = 100)	% Passing 3/4-inch Sieve (spec value = 70-90)	% Passing No. 4 Sieve (spec value = 40-50)	% Passing No. 10 Sieve (spec value = 0-10)	% Passing No. 200 Sieve (spec value = 0-5)	Met Project Requirements?
LCRS-13	Sieve	Onsite, 1.5-inch minus	E-6 sump, above 1-ft LCRS layer on floor	N/A	100	54.6	3.0	2.8	1.3	Yes (per RFI No. 41)
LCRS-14	Sieve and Permeability	Onsite	E-6 (Partial), 1-ft LCRS layer on cell floor and sump	2.14	100	100	1.3	1.0	0.3	Yes (per RFI No. 52.1)
LCRS-15	Sieve Analysis and Permeability	Halawa Quarry	E-6 (Partial), 1-ft LCRS layer on cell floor and sump	2.23	100	99.4	2.6	1.6	1.3	Yes (per RFI No. 52.1)

Sample ID	Test Requested	Source and Material Type	Location Used	Hydraulic Cond. (cm/sec) (spec value >/= 1.0)	% Passing 1.5-inch Sieve (spec value = 100)	% Passing 3/4-inch Sieve (spec value = 70-90)	% Passing No. 4 Sieve (spec value = 40-50)	% Passing No. 10 Sieve (spec value = 0-10)	% Passing No. 200 Sieve (spec value = 0-5)	Met Project Requirements?
LCRS-16	Sieve Analysis and Permeability	Halawa Quarry	E-6 (Partial), 1-ft LCRS layer on cell floor and sump	2.01	100	97.0	5.0	4.9	2.9	Yes (per RFI No. 52.1)
LCRS-17	Sieve Analysis	Halawa Quarry	E-6 (Partial), 1-ft LCRS layer on cell floor and sump	N/A	100	99.3	3.9	3.9	2.9	Yes (per RFI No. 52.1)
LCRS-18	Sieve Analysis	Onsite, 1.5-inch minus	E-6 sump, above 1-ft LCRS layer on floor	N/A	100	43.6	3.4	3.0	1.4	Yes (per RFI No. 41)
LCRS-19	Sieve Analysis and Permeability	Onsite, 1.5-inch minus	E-6 sump, above 1-ft LCRS layer on floor	2.09	100	46.6	3.6	3.3	1.7	Yes (per RFI No. 41)

cm/sec centimeters per second
N/A not applicable

3.2.6 Operations Layer

CQA monitors observed placement of the 2-ft-thick operations layer above the LCRS drainage gravel, and up the sideslope 10 ft, as required by the project Construction Drawings (Geosyntec 2010). The material used to construct the 2-ft-thick layer above the LCRS drainage gravel was comprised of 2-inch minus gravel material generated from onsite screened soil/rock materials.

In addition, a 3-ft-thick operations layer was observed being placed over the liner termination on the benches of Cell E-6. Material used to construct the 3-ft-thick layer on the termination bench was comprised of 3/8-inch minus sand material and was generated from onsite screened soil/rock materials.

Bulk samples of the materials were sampled and tested for sieve analysis and hydraulic conductivity. The sample material, gradation, and hydraulic conductivity results are presented in Appendix C.3 and summarized in Table 3-6.

Table 3-6: Operations Layer Laboratory Testing Results

Sample ID	Test Requested	General Material Description	Location Used	Hydraulic Cond. (cm/sec) (spec value >/= 0.01)	% Passing 2-inch Sieve (spec value = 100)	Met Project Requirements?
OPS-03	Sieve and Permeability	2-inch minus gravel	Floor area and 10-ft up sideslopes	1.09	100	Yes
OPS-04	Sieve and Permeability	3/8" minus soil cushion	Termination benches	0.0296	100	Yes
OPS-05	Sieve and Permeability	3/8" minus rock chip	Floor area and 10-ft up sideslopes	0.112	100	Yes
OPS-06	Sieve and Permeability	2-inch minus gravel	Floor area and 10-ft up sideslopes	2.21	100	Yes

The hydraulic conductivity measured for all samples met or exceeded the minimum requirement of 0.01 cm/sec. The maximum particle size of all samples was below the required maximum size of 2 inches. Approximately 6,820 yd^3 of operation layer material was placed, resulting in a testing frequency of one test per 1,705 yd^3 (no minimum testing frequency is specified in the project Technical Specifications or CQA Plan).

3.3 GEOMEMBRANE INSTALLATION

3.3.1 General

Installation of the geomembrane was observed, monitored, and documented by AECOM CQA personnel on a full-time basis. The following CQA activities were performed during installation:

- Coordination and review of manufacturers' quality control (QC) documentation and conformance testing results
- Observing and documenting geomembrane deployment procedures
- Monitoring and documenting trial seam procedures (trial welds) and evaluation of test results
- Observing and documenting field seams and seaming operations
- Observing and documenting non-destructive seam continuity testing
- Identifying destructive sample locations for seam strength testing
- Identifying and documenting defects and observing and documenting repairs

A detailed description of the CQA program for each of the above activities is presented below.

3.3.2 Manufacturer's Quality Control Documentation and Conformance Testing

Included in Appendix F.1 are the manufacturer's QC documents and conformance testing results for the 40-mil and 60-mil HDPE geomembrane material. Conformance sampling and testing was performed by TRI/Environmental Inc. of Austin, Texas and reviewed by Geosyntec. AECOM also reviewed the results and confirmed all testing met project Technical Specifications (Geosyntec 2010). Geomembrane conformance laboratory testing results are summarized in Table 3-77 and Table 3-88.

A total of 47 rolls (740,250 ft^2) of 40-mil HDPE geomembrane was delivered to the site for construction of MSW Cells E-5 through E-6 and for the Phase II and Phase III West Berm final cover.

Nine samples of the 40-mil geomembrane were conformance tested at a sampling frequency of one sample for every 82,250 ft^2 of 40-mil, which complies with the minimum sampling frequency of one sample per 100,000 ft^2 required by the Project Technical Specifications.

A total of 49 rolls (573,300 ft^2) of 60-mil HDPE geomembrane was delivered to the site for construction of MSW Cells E-5 through E-6 and for the Phase II and Phase III West Berm final cover. Seven samples of the 60-mil geomembrane were conformance tested at a sampling frequency of one sample for every 81,900 ft^2 of 60-mil, which complies with the minimum sampling frequency of one sample per 100,000 ft^2 required by the project Technical Specifications (Geosyntec 2010).

3.3.3 Geomembrane Deployment

The surface of each deployed geomembrane panel was examined for defective areas, flaws, and damage. Unacceptable areas that were identified during routine observation were marked by both AEG and/or AECOM and repaired by AEG.

Each panel was assigned a field identification number and stationed when in place. Panel numbers were used to identify seams, and stationing was used to reference testing and repair procedures. Stationing of the panels began with station 0+00 being assigned to the beginning of the panel at the top of the slope. The numbers ran from the top of the slope, down slope, on to the Cell E-6 floor. Measurements were made using a measuring wheel on the surface of the deployed panel.

Roll numbers were also assigned to each roll of geomembrane liner by the manufacturer during production of the material. These numbers were used in referencing a particular roll to the corresponding manufacturer's quality control test results included in this report.

The following designation was used for the geomembrane panels:

- **S1-#**. 40-mil panel from lower section of double composite liner system in E-6 sump
- **P1-#**. 60-mil panel from lower section of double composite liner system in E-6 sump
- **S2-#**. 40-mil panel from upper section of double composite liner system in E-6 sump
- **P2-#**. 60-mil panel from upper section of double composite liner system in E-6 sump
- **S-#**. 40-mil panel from single composite liner system outside of E-6 sump
- **P-#**. 60-mil panel from single composite liner system outside of E-6 sump

For each panel placed, the number of the roll from which the panel was taken was recorded. A list of the panels and corresponding roll numbers is presented on the Panel Placement forms in Appendix E.3. Panel overlaps were observed by AECOM to verify that they met the project specifications.

The AECOM CQA monitor observed that the deployment method approved by RFI Nos. 044 and 049 for installation of geosynthetics from the western slope runout bench, was followed. The installer was allowed to drive the forklift over the previously installed geosynthetic layers to install the overlying layers using plywood pieces covered in geotextile. The CQA monitor observed the condition of the liner after each plywood piece was moved forward and documented liner conditions in daily reports and with photo documentation.

Records of geomembrane panel, destructive samples, and significant repair locations are shown in Appendix I on Drawings 2 through 7.

3.3.4 Trial Welds

Trial weld samples were produced several times during each day's production seaming. The seams were made by AEG technicians on representative pieces of the geomembrane to monitor each seaming apparatus and operator under the daily site conditions. Trial welds were performed once in the morning and again during early afternoon. The trial seams were observed, monitored, and documented by AECOM.

Trial weld samples were a minimum of 5-ft-long by 1-ft-wide after seaming, with the seam centered lengthwise. Two specimens, measuring 1-inch-wide, were die-cut from each trial seam. The specimens were tested by AEG, for peel adhesion and bonded seam strength (shear strength) using an onsite tensiometer supplied by AEG.

For the 40-mil geomembrane, the specified strength criteria for peel adhesion were 60 pounds per inch (ppi) for fusion welds and 52 ppi for extrusion welds. The specified strength criteria for all shear specimens (fusion and extrusion) were 80 ppi. In addition to the strength criteria, specimens were required to fail outside of the weld area in a film tear bond.

For the 60-mil geomembrane, the specified strength criteria for peel adhesion were 91 ppi for fusion welds and 78 ppi for extrusion welds. The specified strength criteria for all shear specimens (fusion and extrusion) were 120 ppi. In addition to the strength criteria, specimens were required to fail outside of the weld area in a film tear bond.

When failures occurred during the trial welds, the seamer was required to perform a second trial weld using the same welding machine used for the first weld. The second trial welds were tested using the same procedure as the first trial welds.

Production seaming was conducted after passing results on trial welds were achieved. Each trial seam was assigned a number, and pertinent information was recorded by AECOM. The summary of the 170 trial weld seam results from the Cell E-6 (Partial) installation is presented in Appendix E.2.

3.3.5 Geomembrane Seaming

AECOM observed and documented seam preparation such as sufficient sheet overlap; absence of dirt, dust, and moisture; and proper grinding techniques (for extrusion welding). The CQA staff also monitored the following during seaming: ambient temperature, panel overlap, welding machine temperature and speed, and conformance with trial weld parameters.

Seams were identified by the CQA staff using the panel numbers joined by the seam. For example, seam number 3/4 is located between panel numbers 3 and 4. Production seam lengths extended to the top of the anchor trench (back crest of the slope).

The entire length of each seam was visually examined for quality. Imperfections in the seam were either marked by AECOM or AEG and were subsequently repaired by AEG. Additionally, the QC technician from AEG occasionally removed a test strip from the production seams and tested the strip in the field using the tensiometer.

A total of 23,289 lf of geomembrane seams were welded for this project. Details of the panel seams by layer are provided on the Panel Seaming Summaries in Appendix E.4.

Table 3-7: Geomembrane Conformance Testing Results (40-mil)

Sample ID (GSE Roll Number)	Thickness ASTM D5994 (mils) Spec Min. value = 36 Avg. = 40	Asperity GM No. 12 (mils) Spec Min value = 20	Density ASTM D1505 (g/cm^3) Spec Min. Value = 0.940 Max. Value = 0.950	Carbon Content ASTM D4218 (%) Spec Range Value = 2.0 – 3.0	Carbon Dispersion ASTM D5596 (Cat Rating) 9 of 10 Cat 1 or 2, 1 of 10 Cat 3	Tensile ASTM D6693 Spec Min. Value = 84, 60,12,100	Meets Project Requirements?
102151727	Min. = 42 Avg. = 45	Side A: 28 Side B: 28	0.944	2.50	1 (5), 2 (5)	MD = 115, 141, 18, 468 TD = 120, 116, 16, 374	Yes
102151733	Min. = 39 Avg. = 43	Side A: 30 Side B: 33	0.944	2.61	1 (5), 2 (5)	MD = 115, 137, 17, 453 TD = 120, 117, 15, 374	Yes
102151740	Min. = 40 Avg. = 43	Side A: 30 Side B: 32	0.944	2.54	1 (7), 2 (3)	MD = 114, 135, 18, 451 TD = 120, 124, 16, 425	Yes
102151747	Min. = 37 Avg. = 42	Side A: 30 Side B: 32	0.944	2.49	1 (7), 2 (3)	MD = 112, 144, 17, 488 TD = 119, 121, 15, 350	Yes
102151753	Min. = 37 Avg. = 40	Side A: 31 Side B: 33	0.944	2.55	1 (3), 2 (7)	MD = 111, 125, 19, 388 TD = 118, 119, 15, 395	Yes
102151759	Min. = 43 Avg. = 49	Side A: 36 Side B: 35	0.945	2.57	1 (9), 2 (1)	MD = 113, 145, 22, 479 TD = 124, 131, 18, 470	Yes
102151765	Min. = 40 Avg. = 43	Side A: 28 Side B: 33	0.944	2.50	1 (7), 2 (3)	MD = 117, 145, 22, 475 TD = 120, 127, 18, 435	Yes
102151773	Min. = 41 Avg. = 46	Side A: 33 Side B: 36	0.944	2.59	1 (10)	MD = 120, 148, 18, 467 TD = 122, 120, 15, 333	Yes
102151778	Min. = 41 Avg. = 47	Side A: 35 Side B: 34	0.945	2.52	1 (6), 2 (4)	MD = 118, 137, 18, 432 TD = 123, 124, 16, 387	Yes

Note: Tensile properties results are shown in order for Yield Strength (lb/in), Break Strength (lb/in), Elongation at Yield (%), and Elongation at Break (%).
g/cm^3 grams per cubic centimeter
lb/in pounds per inch
MD machine direction
TD transverse direction

Table 3-8: Geomembrane Conformance Testing Results (60-mil)

Sample ID (GSE Roll Number)	Thickness ASTM D5994 (mils) Spec Min. value = 54 Avg. value = 60	Asperity GM No. 12 (mils) Spec Min value = 20	Density ASTM D1505 (g/cm^3) Spec Min. Value = 0.940 Max. Value = 0.950	Carbon Content ASTM D4218 (%) Spec Range Value = 2.0 – 3.0	Carbon Dispersion ASTM D5596 (Cat Rating) 9 of 10 Cat 1 or 2, 1 of 10 Cat 3	Tensile ASTM D6693 Spec Min. Value = 126, 90,12,100	Meets Project Requirements?
102151569	Min. = 56 Avg. = 63	Side A: 30 Side B: 23	0.946	2.59	1 (10)	MD = 169, 196, 20, 491 TD = 173, 144, 18, 357	Yes
102151580	Min. = 64 Avg. = 64	Side A: 31 Side B: 29	0.944	2.50	1 (10)	MD = 168, 188, 18, 472 TD = 171, 160, 18, 426	Yes
102151588	Min. = 61 Avg. 64	Side A: 23 Side B: 21	0.944	2.60	1 (10)	MD = 172, 185, 18, 448 TD = 173, 170, 17, 399	Yes
102151601	Min. = 59 Avg. = 63	Side A: 29 Side B: 25	0.944	2.55	1 (10)	MD = 169, 168, 19, 316 TD = 171, 144, 18, 298	Yes
102151706	Min. = 59 Avg. = 65	Side A: 35 Side B: 34	0.944	2.51	1 (4), 2 (6)	MD = 176, 187, 19, 420 TD = 176, 179, 18, 445	Yes
102151714	Min. = 58 Avg. = 63	Side A: 34 Side B: 32	0.945	2.58	1 (1), 2 (9)	MD = 173, 177, 19, 393 TD = 185, 186, 20, 424	Yes
102151722	Min. = 58 Avg. = 63	Side A: 33 Side B: 33	0.944	2.45	1 (2), 2 (8)	MD = 173, 189, 19, 460 TD = 174, 179, 18, 449	Yes

Note: Tensile properties results are shown in order for Yield Strength (lb/in), Break Strength (lb/in), Elongation at Yield (%), and Elongation at Break (%).

3.3.6 Seam Strength Non-Destructive Testing

All geomembrane seams were non-destructively tested. Fusion welded seams were air pressure tested, and extrusion welds were vacuum box tested. AEG performed all non-destructive HDPE geomembrane testing. AECOM CQA personnel observed non-destructive testing procedures and documented test location, test information, identity of AEG seaming technician, and the test results. Non-destructive seam testing information is provided for the multiple layers of 40-mil and 60-mil geomembrane in Appendix E.5.1 through E.5.4.

To begin air pressure testing of a fusion weld, the air channel between the two "tracks" of the fusion was heat sealed on both ends of the seam to provide a completely closed air chamber along the length of the seam. Next, a hollow needle, fitted into a pressure gauge, was inserted into the air chamber. The air in the channel was pumped to a pressure between 30 and 35 pounds per square inch (psi) and the pressure in the channel was allowed to stabilize for 2 minutes. After stabilizing, the beginning pressure was recorded and the seam was tested for at least 5 minutes. If the pressure dropped more than 2 psi during the 5-minute test, the seam was considered to have failed the test.

At the end of the 5-minute test period, the AEG technician walked to the end of the seam opposite from the pressure gauge and pierced the air channel. AECOM CQA personnel observed the needle on the pressure gauge drop. A drop in pressure indicated that the air channel had not been blocked and the entire seam had been tested. If the air pressure did not drop, the blockage in the air channel was located, marked for repair, and air testing was conducted on both sides of the blockage.

If a seam failed air pressure testing, the area where the needle was inserted into the air channel was checked for leaks. Next the heat-sealed ends of the seam were checked for leaks. If no air was found to be leaking at these locations, the AEG technician performed a visual inspection of the seam. If the leak was located visually, the seam was cut on either side of the leak, the air channel was heat sealed between the "tracks," and the seam was retested in both directions. If the retest failed, or the leak was not found visually, the seam was either capped by extrusion welding a 1- to 2-ft-wide piece of geomembrane over the failed seam or by extrusion welding the panel overlap to the geomembrane panel. All repaired seams were non-destructively tested using the vacuum box method.

Upon completion of air pressure testing, repairs were made to the areas where needles had been inserted, air channels had been pierced, and blockages or leaks had been identified. These repairs included placing extrusion beads and welding patches over the holes and blockages, using the techniques described in Section 2.3.2.4. These repairs were also non-destructively tested using the vacuum box method, described below.

Extrusion welds were non-destructively tested using a vacuum box. The vacuum box is an 8-inch by 24-inch cast aluminum frame fitted with a clear plastic viewing window and a neoprene rubber seal. A pressure gauge is mounted inside the box.

The test procedure involved applying a soapy solution to the weld. The vacuum box was then placed over the weld and a negative pressure of 5 psi was developed in the box. This test pressure was held on the weld for a minimum of 10 seconds. If there was a leak in the weld, the vacuum drew air from under the liner, through the leak, and visible bubbles develop in the soapy solution and were seen through the viewing window. If no air bubbles appeared, the weld section being tested was considered to have passed.

Where air bubbles were visible, the leak was marked on the liner, and repaired using the techniques described in Section 2.3.2.4. Vacuum box testing was performed with a minimum overlap of 3 inches between tests as the vacuum box was moved along the seam length. Results for the vacuum box testing of each extrusion repair and extrusion seam are summarized on the Geomembrane Repair Summary Appendix E.8 and the Nondestructive Seam Testing Summary forms in Appendix E.5.

3.3.7 Seam Strength Destructive Testing

Destructive samples were obtained from representative seams to perform laboratory testing of the seam integrity. A total of 54 destructive test samples were obtained from the 23,289 lf of 40-mil and 60-mil seaming. This equates to an approximate frequency of one test per 431 ft of seam, which meets the required minimum testing frequency of 1 per 500 ft of seam. Test locations were selected by the AECOM representative based on the progress of a particular machine, the suspicion of seam integrity, or to maintain a random testing pattern. Tests locations were also selected at specific locations to include both the 40-mil and 60-mil material, encapsulating welds, panel seams, tie-in to existing liner, and caps.

Destructive samples were first tested in the field by AEG's QC representative with a portable tensiometer. The calibration certificate for the tensiometer is included in Appendix D.1. Test strips were cut from the destructive sample and tested for peel adhesion and shear strength. If the field strips passed, a portion of the remaining destructive test sample was sent to the geosynthetics laboratory for testing. The laboratory sample was subsequently cut into 10, 1-inch-wide test specimens using a hydraulic press equipped with a 1-inch by 10-inch die.

For extrusion samples, five of the test specimens were tested for shear and five were tested for peel adhesion strength. Fusion seam samples had five specimens tested for shear strength and five for peel adhesion also. In accordance with specifications, peel testing was conducted on both tracks of the weld. The testing was conducted at a constant rate of elongation of 2 inches per minute. The yield load and the mode of failure for each specimen were recorded.

For the 40-mil, the acceptance criterion for shear specimens was that 4 out of 5 specimens have yield strengths of 80 ppi or greater and that failure should not occur in the weld. The acceptance criteria for peel specimens was that 4 out of 5 specimens have yield strengths equal to or exceeding 52 and 60 ppi for extrusion and fusion seams, respectively, and that failure should not occur in the weld.

For the 60-mil, the acceptance criterion for shear specimens was that 4 out of 5 specimens have yield strengths of 120 ppi or greater and that failure should not occur in the weld. The acceptance criteria for peel specimens was that 4 out of 5 specimens have yield strengths equal to or exceeding 78 and 91 ppi for extrusion and fusion seams, respectively, and that failure should not occur in the weld.

The summaries for both the fusion seam and the extrusion seam destructive test results are presented in Appendix E.6. Laboratory data sheets are provided in Appendix E.7. All destructive samples met the requirements outlined in the project Technical Specifications (Geosyntec 2010).

3.3.8 Geomembrane Repairs

The repairs and defects requiring patches were documented by recording the date repaired, location, description of damage, size and type of repair, crew that made the repair, date and technician that conducted the non-destructive test on the repair. Repair caps were subject to the same quality control procedures as the field seams including pre-production testing and vacuum box testing.

Dates and locations of repairs to the geomembrane can be found on the Geomembrane Repair Summary in for the multiple layers of 40-mil and 60-mil geomembrane in Appendix E.8.1 through Appendix E.8.4.

3.4 GCL INSTALLATION

3.4.1 Conformance Testing and Manufacturer's QC Documentation

A total of 709,125 ft^2 of NWL-60 GCL was delivered to the site for construction of MSW Cells E-5 through E-6 and for the Phase II and Phase III West Final Berm final cover. Eight samples of the

GCL were conformance tested, which resulted in a sampling frequency of one sample for every 88,641 ft^2 of GCL, which complies with the minimum sampling frequency of one sample per 100,000 ft^2 required by the Project Technical Specifications.

The manufacturer's QC documents and conformance testing results for the NWL-60 GCL material are included in Appendix F.2. Conformance sampling and testing was performed by TRI/Environmental Inc. of Austin, Texas and reviewed by the design engineer Geosyntec. AECOM also reviewed the results and confirmed all testing met project specifications. GCL conformance laboratory testing results are summarized in Table 3-910.

3.4.2 Delivery and Onsite Storage

The GCL materials used for Cell E-6 (Partial) were delivered in semi-trailers and unloaded by Goodfellow Bros. personnel. Rolls were then placed on wood pallets and covered with a plastic tarp. The GCL roll numbers were logged and the material was inspected for damage prior to deployment. See Appendix G for inventory information.

3.4.3 Placement Methods

The GCL was deployed by pulling the panels by hand down the slope. The GCL was deployed in a manner not to entrap stones or other loose soil under the material. AECOM CQA monitors observed that the GCL was placed in accordance to the specifications and as described in Section 2.3.3.

A list of the GCL roll numbers installed for the E-6 (Partial) project is presented in the GCL Material Inventory in Appendix G.1.

3.5 INTERFACE FRICTION TESTING

Interface friction testing was performed for the soil against GCL and geomembrane, the GCL against geomembrane, and the geomembrane against geotextile conditions. Two separate tests were performed on the GCL against the geomembrane, and included a wet and a dry test. The average of the wet and dry post-peak shear stresses was used to calculate the post-peak shear strength. Testing was performed by TRI/Environmental, Inc., and test results are presented in Appendix F.3. All interface results met the required project Technical Specifications (Geosyntec 2010) and are summarized in Table 3-10 through Table 3-13.

3.6 GEOTEXTILE CUSHION AND FILTER GEOTEXTILE LAYER INSTALLATION

AECOM provided full-time observation of the 16 oz/yd^2 and 10 oz/yd^2 geotextile deployment for Cell E-6 (Partial). The 16 oz/yd^2 geotextile provided a cushion over the geomembrane prior to the LCRS drainage gravel placement. The 10 oz/yd^2 geotextile provided a filter layer over the LCRS drainage gravel. The CQA monitor observed and recorded deployment and sewing methods used.

Geotextile in areas that had received 3-inch minus backfill to achieve final grade were overlapped a minimum of 3 inches, and sewn in place with a double-stitched "prayer" seam. This area included the northern edge Cell E-6 (Partial), north of the 440-ft contour. Areas outside of the backfilled area were overlapped with a 3-ft overlap, shingled with the up-canyon layer over the down-canyon layer, as outlined in RFI No. 53 (which is summarized in Section 3.9 and presented in Appendix J).

A list of the roll numbers installed for the E-6 (Partial) project is presented in the Geotextile Material Inventory in Appendix G. 3.

Table 3-9: NWL-60 GCL Conformance Testing Results

Sample ID (Bentofix Roll Number)	Mass/Unit Area ASTM D5993, (lb/ft^2) Spec Min. Value = 0.75	Moisture Content ASTM D2216, (%) Spec Max. Value = 12	Free Swell Index ASTM D5890 (ml/2g) Spec Min. Value = 24	Fluid Loss, ASTM D5891 (ml) Spec Max. Value = 18	Index Flux ASTM D5887 ($m^3/m^2/sec$) Spec Max. Value = 1E–8	Peel Strength ASTM D6496 (lb/in) Spec Min. Value = 2.5	Hydraulic Conductivity ASTM D5084 (cm/sec.) Spec Max. Value = 5E–9	Meets Project Requirements?
502153658	0.87	10.6	28	14.0	3.1E–9	18.7	3.0E–9	Yes
502153706	0.88	10.5	30	14.8	3.2E–9	18.3	3.2E–9	Yes
502154139	0.81	8.4	31	15.0	3.4E–9	14.3	3.0E–9	Yes
502154088	0.85	9.4	30	14.0	3.0E–9	15.5	2.7E–9	Yes
502154174	0.84	10.2	31	13.0	3.1E–9	13.4	3.0E–9	Yes
502154393	0.93	9.5	29	13.2	3.5E–9	14.1	3.7E–9	Yes
502154427	0.88	10.9	29	14.0	3.0E–9	13.4	2.8E–9	Yes
502154474	0.83	10.5	28	14.0	3.2E–9	13.5	2.8E–9	Yes

$m^3/m^2/sec$ cubic meters per square meter per sec
ml milliliters
ml/2g milliliters per 2 grams

WMH001013

3.6.1 Conformance Testing and Manufacturer's QC Documentation

Included in Appendix F.4.1 and F.4.2 are the manufacturer's QC documents and conformance testing results for the 16-oz/yd^2 and 10-oz/yd^2 geotextile material, respectively. Conformance sampling and testing was performed by TRI/Environmental Inc. of Austin, Texas and reviewed by Geosyntec. AECOM reviewed the results and confirmed all testing met project specifications. Geotextile conformance laboratory testing results are summarized in

Table 3-14 and Table 3-15.

A total of 122 rolls (549,000 ft^2) of 16-oz/yd^2 geotextile were delivered to the site for the construction of MSW Cells E-5 through E-6 and for the Phase II and Phase III West Final Berm final cover. Six samples of the 16-oz geotextile were conformance tested at a sampling frequency of one sample for every 91,500 ft^2. The geotextile conformance testing complies with the minimum sampling frequency of one sample per 100,000 ft^2 required by the specifications.

A total of 42 rolls (189,000 ft^2) of 10-oz/yd^2 geotextile were delivered to the site for the construction of MSW Cells E-5 through E-6 and for the Phase II and Phase III West Final Berm final cover. Two samples of the 10-oz geotextile were conformance tested at a sampling frequency of one sample for every 94,500 ft^2. The geotextile conformance testing complies with the minimum sampling frequency of one sample per 100,000 ft^2 required by the specifications.

Table 3-10: Interface Friction Testing Results, 16-oz/yd^2 Non-woven Geotextile (Roll No. 130355906) vs. 60-mil HDPE DST Geomembrane (Roll No. 102151569)

Normal Stress (psf)	Minimum Required Sheer Strength at Post-Peak Conditions (psf)	Tested Corrected Large Displacement Sheer Stress (psf)	Meets Project Requirements?
1,000	249	433	Yes
2,500	623	924	Yes
5,000	1,247	2,014	Yes
10,000	2,493	3,057	Yes
15,000	3,740	4,899	Yes

DST double-sided textured
psf pounds per square foot

3.7 LCRS INSTALLATION

3.7.1 Visual Observation

During construction, the AECOM CQA Monitor observed that the aggregate used for LCRS drainage gravel was consistent throughout the project. The CQA monitor also continuously monitored material placement to ensure that minimum thickness was being achieved and that the equipment did not damage the underlying geosynthetics. Testing of the LCRS drainage gravel was conducted and was summarized in Section 3.2.5.

3.7.2 Stormwater Diversion Berm

A temporary 4.5-ft high stormwater diversion berm was constructed along the floor of at the northern border of Cell E-6 (Partial). The diversion berm was constructed to ensure that stormwater generated up-canyon of new cell does not immediately flow onto the lined cell resulting in increased leachate generation. The berm was constructed with soil cushion material in accordance with the project Construction Drawings (Geosyntec 2010). The berm was surveyed and is shown on Drawing 8 in Appendix I.

Table 3-11: Interface Friction Testing Results, NWL-60 GCL – Non-Woven Side (Roll No. 502153658) vs. GSE 60-mil HDPE DST Geomembrane (Roll No. 102151569)

Normal Stress (psf)	Minimum Required Average Sheer Strength at Post-Peak Conditions (psf)	Tested Corrected Large Displacement Sheer Stress – Wet (psf)	Tested Corrected Large Displacement Sheer Stress – Dry (psf)	Average Corrected Large Displacement Sheer Stress – Wet/Dry (psf)	Meets Project Requirements?
1,000	249	431	462	446.5	Yes
2,500	623	957	890	923.5	Yes
5,000	1,247	2,472	2,309	2,390.5	Yes
10,000	2,493	2,491	2,953	2,722	Yes
15,000	3,740	3,566	5,304	4,435	Yes

Table 3-12: Interface Friction Testing Results, NWL-60 GCL – Scrim Side (Roll No. 502153658 and Roll No. 502153679) vs. GSE 40-mil HDPE DST Geomembrane (Roll No. 102151727)

Normal Stress (psf)	Minimum Required Average Sheer Strength at Post-Peak Conditions (psf)	Tested Corrected Large Displacement Sheer Stress – Wet (psf)	Tested Corrected Large Displacement Sheer Stress – Dry (psf)	Average Corrected Large Displacement Sheer Stress – Wet/Dry (psf)	Meets Project Requirements?
1,000	249	453	529	491	Yes
2,500	623	905	943	924	Yes
5,000	1,247	1,621	1,699	1,660	Yes
10,000	2,493	4,281	3,081	3,681	Yes
15,000	3,740	3,953	5,210	4,581	Yes

Table 3-13: Interface Friction Testing Results, Cushion Layer Soil vs. GSE 40-mil HDPE DST Geomembrane (Roll No. 102151727)

Normal Stress (psf)	Minimum Required Sheer Strength at Post-Peak Conditions (psf)	Tested Corrected Large Displacement Sheer Stress (psf)	Meets Project Requirements?
1,000	249	792	Yes
2,500	623	1,803	Yes
5,000	1,247	3,779	Yes
10,000	2,493	8,321	Yes
15,000	3,740	7,928	Yes

Table 3-14: Geotextile Conformance Testing Results (10 oz/yd^2 Non-Woven)

Sample ID (GSE Roll Number)	Mass/Unit Area ASTM D5261 (oz/yd^2) Spec Min. value = 10	Grab Tensile ASTM D4632 (lbs) Spec Min value = 260	Puncture Resistance ASTM D4833 (lbs) Spec Min. Value = 180	Trapezoidal Tear ASTM D4533 (lbs) Spec Min. Value = 100	Burst Strength ASTM D3786 (psi) Spec Min. Value = 520	Apparent Opening Size ASTM D6693 (mm) Spec Max Value = 0.21	Permittivity ASTM D4491 (s-1) Spec Min. Value = 1.2	Meets Project Requirements?
130356014	10.9	MD = 347 TD = 426	188	MD = 144 TD = 203	560	0.075	1.46	Yes
130356036	10.7	MD = 348 TD = 441	190	MD = 149 TD = 213	595	0.075	1.39	Yes

Note: Grab tensile value is the average of machine and transverse direction values.

%	percent
lbs	pounds
psi	pounds per square inches
MD	machine direction
mm	millimeter
oz/yd^2	once per square yard
psi	pounds per square inches
TD	transverse direction

Table 3-15: Geotextile Conformance Testing Results (16 oz/yd^2 Non-Woven)

Sample ID (GSE Roll Number)	Mass/Unit Area ASTM D5261 (oz/yd^2) Spec Min. value = 16	Grab Tensile ASTM D4632 (lbs) Spec Min value = 390	Puncture Resistance ASTM D4833 (lbs) Spec Min. Value = 250	Trapezoidal Tear ASTM D4533 (lbs) Spec Min. Value = 150	Burst Strength ASTM D3786 (psi) Spec Min. Value = 800	Apparent Opening Size ASTM D6693 (mm) Spec Max Value = 0.21	Permittivity ASTM D4491 (s-1) Spec Min. Value = N/A	Meets Project Requirements?
130355858	16.1	MD = 442 TD = 685	267	MD = 194 TD = 316	831	0.075	0.76	Yes
130355880	17.6	MD = 480 TD = 682	289	MD = 187 TD = 336	904	0.075	0.75	Yes
130355902	17.5	MD = 467 TD = 728	299	MD = 199 TD = 349	916	0.075	0.75	Yes
130355924	16.6	MD = 430 TD = 618	267	MD = 205 TD = 315	852	0.075	0.91	Yes
130355946	17.5	MD = 449 TD = 694	299	MD = 223 TD = 378	868	0.075	0.84	Yes
130355968	16.8	MD = 438 TD = 691	289	MD = 210 TD = 356	846	0.075	0.88	Yes

Note: Grab tensile value is the average of machine and transverse direction values.

%	percent
lbs	pounds
psi	pounds per square inches
MD	machine direction
mm	millimeter
oz/yd^2	once per square yard
psi	pounds per square inches
TD	transverse direction

3.7.3 LCRS Riser Pipes

The 18-inch diameter and 24-inch diameter, perforated, SDR-11, HDPE riser pipes were installed in accordance with the project Construction Drawings (Geosyntec 2010). AECOM CQA monitors visually observed that the placement of the pipes did not damage the underlying sump liner and that a rub sheet was placed wherever the pipes contacted the liner on the sump floor. CQA monitors also confirmed that the pipe perforations size and spacing were in accordance with project requirements. The riser pipes were surveyed and the locations and elevations are shown on Drawing 1 in Appendix I.

3.7.4 LCRS Collection Pipe

Approximately 650 lf of 6-inch, SDR-11, HDPE perforated LCRS collection pipe was installed along the floor of the E-6 (Partial) cell in a north-south direction. The pipe was welded and perforated in accordance with the project Technical Specifications and Construction Drawings (Geosyntec 2010). The LCRS collection pipe was fusion welded to the 18-inch LCRS riser pipe in the sump area in accordance with the project Construction Drawings (Geosyntec 2010). The LCRS collection pipe location was surveyed and is shown on Drawing 1 in Appendix I.

3.7.5 LCRS Gas Extraction Pipe

Approximately 180 lf of 6-inch, SDR-11, HDPE, perforated LCRS gas extraction pipe was installed along the toe of the E-6 (Partial) cell. The pipe was welded and perforated in accordance with the project Technical Specifications and Construction Drawings (Geosyntec 2010). The LCRS gas extraction pipe was fusion welded to the 18-inch LCRS riser pipe in the sump area in accordance with the project Construction Drawings (Geosyntec 2010). The LCRS gas extraction pipe location was surveyed and is shown on Drawing 1 in Appendix I.

3.8 Record Drawings and Photo Documentation

Photos of typical construction procedures and important components of the construction are included in Appendix H. Each photograph includes the date and a description of the photo.

Record drawings that document the completed Cell E-6 (Partial) construction are included in Appendix I. Drawing 1 presents a topographic survey by the project licensed surveyor (Park Engineering); drawings 2 through 7 present the panel layouts and repair locations for the various geomembrane layers; and drawing 8 presents the topographic survey of the top of operations layer grade.

3.9 List of Changes from Construction Drawings and Specifications

Changes from construction drawings and specifications were verified with the designer, Geosyntec, via RFIs and are summarized in Table 3-16. Additional information is provided in Appendix J. In general, any change or deviation from the Project Technical Specifications or Construction Drawings (Geosyntec 2010) was documented using a RFI form. Each RFI was assigned a unique number and was tracked using an RFI log.

Table 3-16: Changes from Construction Drawings and Specifications (Cell E-6 [Partial])

Excerpted Original Specification Requirement	Change	Justification
Modification to Specification Section 02249, Compacted Soil (3-Inch Minus)		
Original specification required compaction to 90% of ASTM D1557.	Geosyntec (design engineer) issued a revised specification based on results from a test pad evaluation, and recommended the following for placing and compacting future Compacted Soil material: 1) The Compacted Soil be placed in lifts with maximum loose thickness of 8 inches. 2) A Dynapac CA362D be used to compact the Compacted Soil material 3) The minimum dry unit weight of the material in place after compaction be 122 pounds per cubic foot 4) The dry unit weight be measured by performing sand cone tests (ASTM D1556) 5) The material testing frequencies listed on Table 3-1 of the CQA Manual for the Compacted Soil (3-inch minus) were modified and are presented in the modified specification.	Onsite 3-inch minus fill material has a greater percentage of gravel material than originally anticipated.
RFI No. 002: Cell E-6 Bench Cross Slope		
Drawing No. C-19 of GEI Drainage Plans shows arrows on benches to designate surface water from along bench to collection point at 18" drain line. The contours and typical bench section C/5 show a cross slope of 2% away from the slope, thus draining surface water off the bench rather than toward the 18" drain system.	The contractor requested that the benches in E6 be constructed with a 2% cross slope towards the slope in order to allow surface water to be transferred along the bench to the 18" Drainage System.	Geosyntec agreed with the proposed change.
RFI No. 014: E-6 Sump Information		
Sheet 4 did not provide horizontal or vertical control of the E6 Sump.	The contractor requested additional information in order to proceed with construction of E6 Sump.	Geosyntec provided a table of control points in Sheet No. 4.
RFI No. 027: 3/8" Soil Cushion		
Technical Specification, Section 02249, Part 2.01 states that the soil cushion material should be angular to sub-angular and have a maximum particle diameter of 1/4-inch rounded to sub-rounded.	The earthwork contractor, Goodfellow Bros. Inc, requested that the maximum size of the soil cushion material be increased to 3/8 inch to allow easier placement and compaction of material.	The increase in maximum particle size was approved by the design engineer (Geosyntec), with the requirement that the larger particle be rounded to sub-rounded using visual classification as described in ASTM D2488.
RFI No. 041: LCRS Gradation Specification		
Technical Specification, Section 02227, Part 2.01 identifies a specific gradation for the LCRS 1.5-inch, 3/4-inch, No. 4, No. 10, and No. 200 sieves. In addition, the specification indicates the material should be from an offsite borrow source.	LCRS material was generated on site, and meets the 1.5-inch gradation, and permeability, however did not meet the 3/4-inch, No. 4 or No. 200 gradations.	The onsite generated material and gradation was considered suitable to meet the intent of the design and was approved by the design engineer (Geosyntec). To monitor the percent of fines and ensure they do not affect the permeability, the design engineer increased the frequency of sieve analysis to one test every 750 yd^3.

Excerpted Original Specification Requirement	Change	Justification
RFI No. 044: Termination Runout for Cell E-6		
Detail P on Geosyntec Drawing Sheet No. 8 shows geosynthetics along the western edge of cell E-6 terminating along the bench where the 18-inch HDPE downchute pipe is located.	The CQA Consultant requested information regarding protective measures to allow the installer to drive a rubber-tired forklift over the various layers of geosynthetics in order to deploy multiple layers of E-6 geosynthetics from the bench down the slope.	After completion of test demonstration, a recommended procedure was provided by Geosyntec regarding how to drive a Gradall Model 534D10 over the deployed geosynthetics using pieces of plywood covered in geotextile. The senior engineer recommended that a photo record of each material's condition be kept.
RFI No. 048: Sump Riser Discrepancy		
Geosyntec Sheet No. 9 details 15.5 ft of the Cell 6 sump pump riser pipe in direct contact with the floor of the sump.	The contractor noted that in order for the sump pump riser pipe to be installed at the plan horizontal alignment, the horizontal portion of the pipe and pipe bend must be modified to accommodate the plan grades based on control points issued via RFI 014 response.	Geosyntec requested that the contractor check that the as-built alignment for the 24-inch leachate riser pipe met the points attached to the RFI and that the selected pump and appurtenances could slide through modified fittings and operate. Four design points were listed with northing and easting locations.
RFI No. 049: Termination Runout for Cell E-6		
Geosyntec Drawings, Detail C on sheet no. 5 showed the geosynthetics west perimeter termination.	In order to effectively deploy the multiple layers of geosynthetics in Cell E-6, the liner installer requested to drive a rubber-tired forklift (Gradall) over the various layers of geosynthetics on the bench. The method suggested was the already approved method in RFI No. 44.	Geosyntec attached Page 0660-1B to the RFI response. The attachment provided a procedure to protect the liner materials on the bench during installation.
RFI No. 050: CLSM 150 psi		
Technical Specification, No. 02231 stipulates that "the mix design for the CLSM shall have a minimum unconfined compressive 7-day strength of 150 psi."	The contractor requested to use CLSM that reaches a 28-day compressive strength of 150 psi is used in standard practice.	The use of CLSM that reaches a 28-day compressive strength of 150 psi was approved by the project engineer (GEI Consultants), on the condition that the CLSM would be tested for both 7-day and 28-day break strengths, and the strength test results be forwarded to the CQA manager for the project. The CQA manager was to review the strength test results and advise the design engineers if the CLSM did not meet the specification value of 150 psi after 28-days.
RFI No. 052.1: LCRS Drainage Gravel		
Geosyntec Drawings, Sheet 5, and Technical Specifications Section 02227. The specifications require a 1.5-inch minus gravel material to construct the LCRS drainage gravel layer.	LCRS drainage gravel material in direct contact with the liner system shall be fine crushed rock with a hydraulic conductivity greater than 1.0 cm/sec. Acceptable sample gradation results are attached to the RFI. In the area of the thickened gravel in the Cell 6 sump, the first 1-ft above the liner shall be LCRS-14/LCRS-15 or similar. The remaining 2 ft shall be 1.5-inch minus LCRS material that has a hydraulic conductivity of 1.0 cm/sec or greater (per the original contract specifications).	Owner request to minimize any potential future damage to the liner from poorly graded gravel material.

4.0 CONCLUSIONS

AECOM performed field observations, laboratory testing of materials, and documentation of Cell E-6 (Partial) construction at Waimanalo Gulch Sanitary Landfill.

In summary, based upon our observations and test results, we conclude that the work represented by the attached test results is in substantial conformance with the construction contract documents and their design intent, and industry standard construction practices.

The CQA Officer's Statement is presented in Appendix A.

Appendix A
CQA Officers' Statement

Appendix B
Daily Field Reports

Appendix C
Soil Laboratory Testing

Appendix C.1
Soil Cushion Layer

Appendix C.2
LCRS Drainage Gravel

Appendix C.3
Operations Layer

Appendix C.4
Nuclear Gauge Tests

Appendix C.5
CLSM Tests

Appendix C.6
Sand Cone Tests

Appendix D
Equipment Calibration Certificates

Appendix D.1
Tensiometer Certificate

Appendix E
Geomembrane Installation Documentation

Appendix E.1
Subgrade Acceptance

Appendix E.2
Trial Weld Summary

Appendix E.3
Panel Placement Summary

Appendix E.3.1
40-mil HDPE Panel Placement Summary, Layer S1

Appendix E.3.2
60-mil HDPE Panel Placement Summary, Layer P1

Appendix E.3.3
40-mil HDPE Panel Placement Summary, Layers S2 and S

Appendix E.3.2
60-mil HDPE Panel Placement Summary, Layer P2 and P

Appendix E.4
Panel Seaming Summary

Appendix E.4.1
40-mil HDPE Panel Seaming Summary, S1 Layer

Appendix E.4.2
60-mil HDPE Panel Seaming Summary, P1 Layer

Appendix E.4.3
40-mil HDPE Panel Seaming Summary, S2 and S Layers

Appendix E.4.4
60-mil HDPE Panel Summary, P2 and P Layers

Appendix E.5
Non-Destructive Seam Testing Summary

Appendix E.5.1
40-mil HDPE Non-Destructive Seam Testing Summary, S1 Layer

Appendix E.5.2
60-mil HDPE Non-Destructive Seam Testing Summary, P1 Layer

Appendix E.5.3
40-mil HDPE Non-Destructive Seam Testing Summary, S2 and S Layers

Appendix E.5.4
60-mil HDPE Non-Destructive Seam Testing Summary, P2 and P Layers

Appendix E.6
Destructive Seam Log and Testing Summary

Appendix E.7
Destructive Seam Laboratory Data

Appendix E.8
Geomembrane Repair Summary

Appendix E.8.1
40-mil Geomembrane Repair Summary, Layer S1

Appendix E.8.2
60-mil Geomembrane Repair Summary, Layer P1

Appendix E.8.3

40-mil Geomembrane Repair Summary, Layers S2 and S

Appendix E.8.4
60-mil Geomembrane Repair Summary, Layers P2 and P

Appendix F
Geosynthetic Manufacturer's Quality Control Documents and Conformance Testing

Appendix F.1.1
GCL Material Certifications

Appendix F.1.2
GCL Conformance Testing

Appendix F.2.1
Geomembrane Material Certifications

Appendix F.2.2
Geomembrane Conformance Testing

Appendix F.3
Interface Friction Test Results

Appendix F.4.1
Geotextile Material Certifications

Appendix F.4.2
Geotextile Conformance Testing

Appendix G
Geosynthetic Materials Inventory

Appendix G.1
GCL Material Inventory

Appendix G.2

Geomembrane Material Inventory

Appendix G.3
Geotextile Material Inventory

Appendix H
Cell E-6 (Partial) Photographs

Appendix I
Cell E-6 (Partial) Record Drawings

Appendix J
Field Revisions and Communications